

UNDERSTANDING SOIL ORGANIC MATTER

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Introduction

Recently there has been much discussion on the possibility of storing or sequestering carbon in agricultural soils. Burning of fossil fuels has increased the carbon dioxide (CO₂) level in the atmosphere, which may cause an increase in global temperature. Industrialized countries are considering various methods to lower the level of this greenhouse gas. One possible method is to allow plants to “fix” this carbon. All plants fix CO₂ through photosynthesis and convert it to plant tissue. Carbon is added to the soil when plant tissue decomposes and becomes soil organic matter (OM). If this process increases soil OM, carbon is stored in the soil. Currently, various private groups and governmental organizations are attempting to devise methods of trading soil carbon as an exchangeable commodity. The purpose of this paper is to provide an understanding of soil organic matter and the potential of sequestering carbon in dryland cropping systems of eastern Oregon.

Soil Organic Matter

Soil is a mixture of mineral and organic materials with the mineral component generally far exceeding the organic component. The organic portion, while small in amount, is dynamic and critical to maintaining fertile and productive soils. The organic pool in soil consists of several forms and it is important to distinguish between these forms. Carbon compounds in the soil can be roughly divided into four groups: living organisms, plant residues, active organic matter, and

stable organic matter (Fig. 1). Collectively, stable and active organic matter are considered soil organic matter (SOM), while living organisms and fresh organic residue are too transitory to include. Laboratory procedures for SOM exclude plant tissue and residue before analysis. Soil OM is an array of carbon compounds created by microbes or other organisms through decomposition of plant and animal residues.

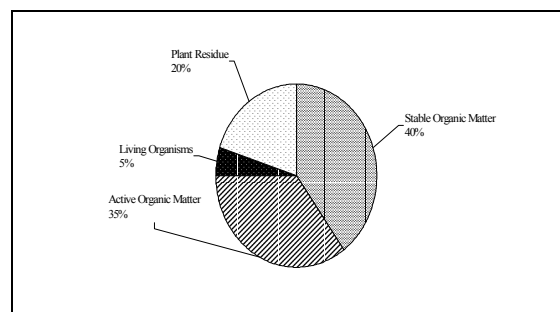


Figure 1. Relative amounts of organic materials in soil.

Content of SOM varies considerably from region to region, field to field, and from summit to foot slope. Generally, SOM is reported on a percentage basis. Agricultural soils in eastern Oregon typically have between 0.5 and 3.0 percent SOM in the surface layer. To convert percent SOM to actual pounds per acre, soil bulk density and depth of sampling must be known. For example, if a soil is sampled 7 in. deep and the bulk density is 1.25 g/cm³ (various methods are available to determine bulk density), then the volume of soil represented by one acre has a weight of approximately 2 million lb. or 1,000 tons. A soil volume of 1 acre x 7 in. deep is

commonly referred to as an “acre-furrow-slice” and unless specified otherwise is usually assumed to be 2 million lb. Using this value, a soil with 1 percent organic matter contains 20,000 lb. or 10 tons SOM per acre (1 percent of 2 million). It is best to use specific bulk densities and sampling depths when making SOM calculations. Table 1 shows the relationship between bulk density, mass of acre-furrow-slice and 1 percent mass. Sandy textured soils may have bulk densities as high as 1.7 g/cm³, while silt loam soils are in the range of 1.2 to 1.3 g/cm³. Thus, a 7-in acre-furrow-slice with 1 percent SOM may contain from 10 to 13 tons SOM/acre, depending on soil bulk density. In most soils, OM content is greatest at the surface and decreases with depth. Thus, depth not only affects the representative volume of soil, but also will affect the concentration of SOM in the sample. A sample taken at a shallow depth will have a higher concentration of SOM, and one taken at a deeper depth will have lower value. The depth to which SOM measurements are taken should always be reported.

Table 1. Relationship between bulk density, weight of acre-furrow-slice and 1 percent mass.

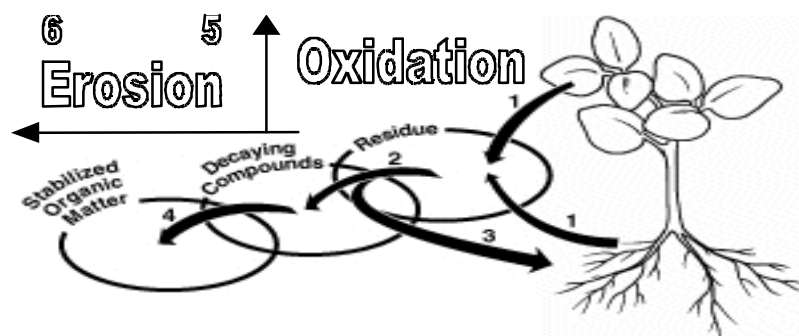
Bulk density (g/cm ³)	Weight of 7-in acre-furrow-slice (lb)	1 percent mass (lb)
1.20	1902701	19027
1.25	1981980	19820
1.30	2061259	20613
1.40	2219818	22198
1.50	2378376	23784
1.60	2536934	25369
1.70	2695493	26955

Role of Soil Organic Matter

Although soil organic matter constitutes a small percentage of soil, it strongly influences many soil properties. As SOM decomposes or mineralizes, it contributes directly to nutrient cycling for plant growth. It increases the nutrient holding capacity of soil by adding to the cation exchange capacity. Soil OM improves soil aggregation, tilth, and aids in preventing crusting and compaction by acting as a binding agent. Water infiltration and water holding capacity are improved by presence of SOM. Organic matter can absorb as much as seven times its own weight in water. Organic matter helps soil resist erosion by increasing soil structure and by improving water infiltration. Organic matter also serves as a chemical buffering agent, resisting changes in pH and binding soil herbicides.

Soil Organic Matter Levels

The amount of organic matter in soil is a function of several factors that affect carbon additions (crop residues or manure) or losses, (decomposition or erosion). The level of organic matter in the soil is a balance between additions and losses (Fig. 2). Plant residues add carbon to the soil while erosion and decomposition remove carbon. Environmental conditions that influence SOM includes annual precipitation, seasonal temperature, soil internal drainage, landscape position, and slope aspect. Conditions or practices that favor additions of organic materials and/or retard losses tend to increase soil OM levels. Those that lessen plant residue inputs and/or hasten losses generally lower soil OM levels. Practices that improve plant growth and/or increasing the amount of residue returned to the soil tends to increase SOM.



1. **Additions.** When plants, roots, and crop residues are added to soil, a fraction of their mass becomes organic matter.
2. **Transformations.** Soil organisms continually change organic compounds from one form to another. They consume plant residue and other organic matter, and then create by-products, wastes, and cell tissue. Most of the carbon in fresh residue is respired off as CO₂, but some converts to more stable forms.
3. **Microbes feed plants.** Some of the wastes released by soil organisms are nutrients that are used by plants or other microbes. Organisms may release other compounds that affect plant growth and the surrounding environment.
4. **Stabilization of organic matter.** Over time, soil organic compounds become stabilized and resistant to further changes.
5. **Oxidation.** When microbes consume soil organic matter and crop residue they respire CO₂, which is released to the atmosphere. Oxidation is favored by warm temperatures, moist soils, and soil mixing.
6. **Erosion.** When erosion occurs, soil organic matter is transported away. On sloping soils, erosion may be the most limiting factor for increasing soil organic matter.

Figure 2. Additions, transformations, and losses of SOM.

Changing Soil Organic Matter and Sequestering Soil Carbon

Rising carbon dioxide levels in the atmosphere have recently been the topic of various international discussions. International agreements have been negotiated to reduce atmospheric levels of CO₂. Soil organic matter is a significant pool that can serve as a reservoir for carbon.

In general, soil OM consists of approximately 60 percent carbon with the

remaining 40 percent consisting of other elements such as oxygen, nitrogen, phosphorus, and sulfur. Using the 60 percent value, a ton of organic matter contains about 1,200 lb. of carbon. The magnitude of the carbon pool in soil is enormous. Assuming the top foot of soil in eastern Oregon's 2 million acres of cropland contains 1 percent (a conservative value) SOM, the size of this pool is about 20 million tons of carbon. If this estimate is extrapolated to all of Oregon, the pool is approximately 700 million tons. The recent emphasis on reducing atmospheric carbon has growers and other

interested people asking “can I sequester carbon in my fields?” To answer this question for dryland fields in eastern Oregon, we can look at soil carbon changes in a series of long-term plots on the Agricultural Research Center, at Pendleton, Oregon. These trials were initiated to study changes in soil properties and crop yields as the result of various management treatments, and have been in place long enough to observe changes in soil carbon. Measurements of SOM have been made at intervals throughout the duration of the trials. Figure 3 shows soil carbon content over time for various cropping and tillage treatments. These treatments represent a range of carbon inputs and tillage intensities. The balance between carbon gains and losses shifts as these factors change. Note that trials do not start at the same dates and that the units are tons of carbon and not OM. To convert to tons of OM multiply these values by 1.67. For reference, 24 and 16 tons of carbon/acre are roughly 3 and 2 percent SOM. Prior to cultivation, the Walla Walla soils at the site had about 3 percent OM or 24 tons carbon/acre in the surface 8 in. At the start of the earliest trials in 1931, the soil had declined to about 2 percent soil OM or 16 tons carbon/acre. Since that time, soil carbon levels have increased or decreased depending on cropping intensity and tillage practice of the various treatments (Table 2). The annual gain or loss in soil carbon is shown in the last line of Table 2.

Soil carbon has continued to decline in all trials except the pasture and continuous, directed seed wheat. Fallow has had the greatest influence on the rate of SOM decline, followed by intensity of tillage. Fallow returns crop residue only every other year and has warm, moist conditions that encourage oxidation of SOM. Tillage increases aeration and consequently enhances oxidation.

If growers want to increase carbon storage in their fields, the amount will depend on the current level of SOM and the changes that can be made in tillage and cropping intensities. For example, if a grower is currently practicing wheat-fallow and moldboard plowing and decides to grow continuous wheat, but still plow, the difference in annual carbon flux (Table 2) is -0.06 to -0.01 ton/acre/year or a change of 0.05 ton/acre/year or 100 lb. In this system, carbon loss is reduced by 100 lb.; however SOM is still declining but at a lower rate. If the grower chose to grow continuous wheat with direct seeding or planted CRP (Conservation Reserve Program) grass (assume that is equal to pasture) the net changes would be 0.13 and 0.16 tons/acre/year respectively, which is 260 and 320 lb. carbon/acre/year and SOM would be increasing.

The answer to “can I sequester carbon?” will depend on current grower practices, existing levels of SOM, and what changes can be made in tillage and crop rotations. A maximum system change of converting from wheat-fallow, moldboard plowing to annual grass (CRP) will result in a capture about 250 lb./acre/year. An additional factor to consider is soil nitrogen. A benefit of organic matter oxidation has been the release of nitrogen for crop. In a situation where carbon is to be sequestered in soil, additional nitrogen will be tied up in the OM. Stable OM has a carbon-to-nitrogen ratio of 12:1. Thus for each 100 lb. of carbon added to soil about 8 lb. of nitrogen must be added. A sequestration rate of 250 lb. of carbon/acre/year would require about 20 lb of nitrogen. At nitrogen prices of \$0.35/lb., that’s about \$7.00 of nitrogen to sequester 250 lb. of carbon/acre/year. Some of the nitrogen can be supplied by natural processes; however, if crops are being

harvested, additional fertilizer nitrogen will be necessary to sequester carbon.

Given the historical change in soil carbon on long-term plots at Pendleton, dryland producers can expect to sequester carbon at the rate of 100-200 lb/acre/year when making significant changes in crop rotation and tillage practices. This rate will depend on the present level of soil OM, reduction in tillage, and increase in cropping frequency (less fallow). More intensive cropping (less fallow) increases carbon inputs and less tillage reduces biological oxidation. Precipitation and temperature will

also have an influence on the rate of sequestration. Pendleton receives about 16 in. of annual precipitation. Areas that are drier will accumulate carbon more slowly, while areas that are wetter will have higher rates of accumulation.

It may be prudent for growers to take advantage of carbon gains if they are changing practices for other reasons. However, changing practices to sequester carbon does not seem feasible at this time. Growers should be cautious when considering possibilities for carbon sequestration.

Table 2. Soil Carbon changes over time on various long-term trials at Pendleton, Oregon

Year	Wheat-Fallow, Plow	Wheat-Fallow, Sweep	Wheat-Green Pea, Plow	Continuous Wheat, Plow	Continuous Wheat, Direct Seed	Pasture
-----Soil Carbon tons/acre in top 8 inches-----						
1931	16		16			16
1956	14.4	14.8	15.2	15.7		18
1981	13.2	14.0	15.0	15.4	17.5	21
Net gain/loss (tons/acre/year)	-0.06	-.04	-0.02	-0.01	+0.07	+0.10

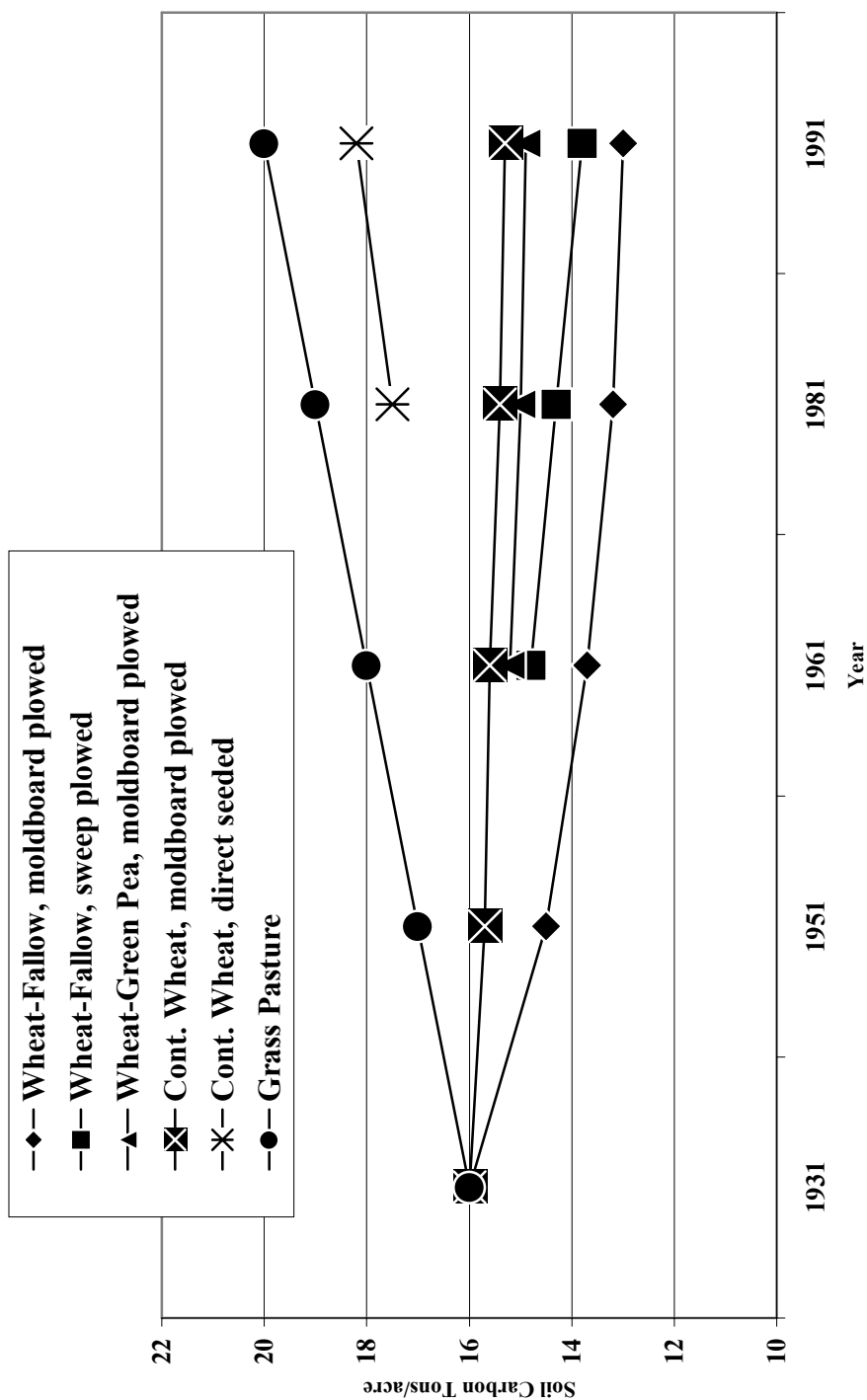


Figure 3. Soil carbon trends in the top 7 in. of soil in various long-term trials at Pendleton, Oregon.